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ABSTRACT

The purpose of this study was to investigate in children from ages 4 to 10 the development of logical propositions and to determine whether or not there is a developmental sequence in children's ability to supply missing elements of syllogisms. A specially designed instrument, consisting of an equal number of items with missing major premises, missing minor premises and missing conclusions, was administered orally to each child (N=140). It was hypothesized that: (1) there will be a significant difference in the scores and proportion of students from age level to age level in the ability to supply missing syllogistic elements; and (2) there will be a hierarchy of difficulty for all subjects in supplying missing portions of syllogisms with the missing conclusion being supplied most frequently, minor premise second most frequently, and major premise least frequently. It was found that (1) there is a developmental sequence in the ability of children from ages 4 to 10 to supply missing elements of syllogisms (the younger the age, the lower is the score), and (2) there is a hierarchy of difficulty for all subjects in supplying some missing portions of syllogisms with the missing conclusion being easier than the missing major premise. These findings lead to questioning Piaget's contention that children are not able to handle formal reasoning until approximately ages 11 or 12. (Author/MP)

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# THE DEVELOPMENT OF CLASS LOGIC IN CHILDREN FROM AGES FOUR THROUGH TEN

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THE DEVELOPMENT OF CLASS LOGIC IN CHILDREN FROM AGES FOUR THROUGH TEN


## Abstract

Hypothesis 1: There will be a significant difference in the proportion of students from age level to age level in supplying missing syllogistic elements. Hypothesis 2: There will be a hierarchy of difficulty in supplying missing syllogistic elements with missing conclusions first, then minor premises, and finally major premises. The sample was comprised of 140 children, 20 each from ages four through ten. A specially designed instrument, reliability .88, was administered orally to each child. A 7 x 2 x 3 factorial ANOVA (age, content, and elements) revealed significant effects of age and element in the direction hypothesized.

# THE DEVELOPMENT OF CLASS LOGIC IN CHILDREN FROM AGES FOUR THROUGH TEN

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There is a growing body of research exploring various aspects of logic including investigations by Gardiner (1965), Ennis and Paulus (1965), Roberge and Paulus (1971) and others. As Roberge's (1972) summary of research indicates, the bulk of the work has utilized subjects from the

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fourth grade up. This may be due in part to Piaget's (1964) influential position that children are not able to handle formal reasoning until around 11 or 12. The few studies that have been conducted with subjects under grade four, which is approximately age ten, provide some evidence of the ability of these younger children to think logically although there are a few problems with the instruments that were used (e.g., Hill, 1961; O'Brien and Shapiro, 1968). Conversations with young children and observations of children in preschool settings by Wolf and Shigaki (1975) provide additional evidence that some children, even as young as four years of age, are beginning to think logically as evidenced by their ability to generate components of a syllogism. A clear example of this ability was illustrated through the following conversation between the four-year-old son of one of the investigators and his father:

> Greg: Do sharks have a lateral line? (The line along the sides of fishes with sensory function).
>
> Father: I don't know Greg.
>
> Greg: But Dad, you said <u>all</u> fish have a lateral line and a shark is a fish.

Similar anecdotes were also heard from other four-year-old children. It was obvious then that at least some children by age four are able to handle some aspects of propositional logic. This provides contradictory evidence to Piaget's claim that formal reasoning does not occur developmentally until age 11 or 12. If Piaget is correct in his claim, one would expect that while a few precocious children might have this ability, there would be little developmental differences among children ages ten and under. Contrary to this position, based on the evidence cited above,

the present investigators maintain that one would expect to find an incremental growth between ages four and ten in the ability to think logically. Consequently, a focal point of the present investigation was to study systematically the development of logical propositions in children from ages four through ten.

The few studies of logic that have been conducted with young children have focused primarily on determining the adequacy of a conclusion to a syllogism. However, it appears that there is a differential ability of children to respond depending upon the element of the syllogism which is being considered. In a previous study by Shigaki and Wolf (1975), recognition of the components of a syllogism by fifth grade subjects appeared to vary in a hierarchical order. The subjects were able to identify 64% of the missing conclusions, 45% of the missing minor premises and 25% of the missing major premises. Hence it appeared that conclusions were the easiest to recognize, followed by minor premises, with major premises being the most difficult to recognize. Consequently, the second objective of the present study was to determine whether or not this hierarchical ordering would hold for younger children when they were required to generate the missing element.

A common mode of instrumentation for research on the logic of children under the age of ten has been the use of concrete materials (Ennis, 1971; Fitzgerald, 1973; Kodroff and Roberge, 1975). Hill devised an instrument which differed by not utilizing concrete materials as facilitators, but which relied instead solely on a verbal presentation. Her findings were questioned by O'Brien and Shapiro who suggested that her yes-no test format lent itself to guessing. They revised her test by including "not

enough clues" in the response choice of some of the items to make them more "open." It was reported that children avoided the more open response, however, even doing poorer than simple random guessing. To minimize the possibility of guessing as in a multiple-choice format and yet to capitalize on the investigators' observations that children are able to perform logical operations on a more abstract verbal level than the manipulation of concrete materials, a completely different type of instrument was created which included an oral presentation requiring children to generate appropriate answers orally.

Hypotheses

The hypotheses of the study were as follows:

Hypothesis 1: There will be a significant difference in the scores and proportion of students from age level to age level in the ability to supply missing elements of syllogisms. The younger the child, the lower will be his score on a test requiring him to generate missing premises or conclusions in syllogisms.

Hypothesis 2: There will be a hierarchy of difficulty for all subjects in supplying missing portions of syllogisms with the missing conclusion being supplied most frequently, minor premise second most frequently, and major premise least frequently.

Sample

Two comparable private schools in New York City with a predominately white middle-class student body constituted the population from which the sample for the study was drawn. While IQ data were not available for the sample, reflecting the general unavailability of IQ scores for children in New York City, school personnel reported that parents of the children were primarily professionals or in the arts, often with both parents

working. It was further reported that the children were very verbal and that achievement tests which were available for the upper grades indicated that some were below grade norms in achievement, some on grade, with the majority performing above grade level. Each school enrolled between 150 and 200 students from ages four through ten. This particular population was selected since the investigators felt that if children were able to respond correctly to the items at the lower age levels it would most probably occur at this type of school. Since the study was to determine if children could respond at all at the various age levels, these schools were considered appropriate for the study. Further, preliminary pilot studies, with middle-class children similar to those in the two schools selected, indicated that the assumption above was in fact a viable one. The sample was comprised of 140 children, 20 from each of the age levels from four through ten. Parental permission for working with each child was required by each school and was received from over 90% of the population. Subjects were randomly selected from those children for whom permission was obtained.

Instrumentation

The instrument for measuring children's knowledge of missing elements in syllogisms was developed with refinements being made based on information acquired through a series of pilot tests. The major problem encountered early in the piloting was the need to "let the children in on the game," i.e., to encourage children who free-associated with the content of the item to work within the closed system of the syllogism. Two modifications were made to alleviate this problem. A sample item

was added to the test to provide the children with specific information concerning the "game." In addition, both nonsense and concrete syllogisms were included to discourage children from merely free-associating with the content of the syllogism. As a result of these refinements, the final instrument which contained twelve items took two basic forms. In one form, six nonsense syllogisms were followed by six concrete syllogisms; in the other form, the order was reversed. An equal number of items with missing major premises, missing minor premises and missing conclusions was included. The single sample item on each test form was one of six varieties distributed equally among the test forms: nonsense or concrete with a missing major premise, missing minor premise or missing conclusion. Finally, to avoid possible reading difficulties, and to accommodate children of ages four and five, the test was developed for oral administration using short syllogisms which could easily be retained. The sample items representing each of the six varieties took the following forms:

| CONCRETE | NONSENSE |
|---|---|
| Missing major premise | |
| Carroll is a clown. | Carroll is a teg. |
| Therefore, Carroll dances. | Therefore, Carroll dances. |
| Why? (How do you know?) | Why? (How do you know?) |
| Missing minor premise* | |
| Only animals have fur. | Only wumps have fur. |
| Marion has fur. | Marion has fur. |
| Why? (How do you know?) | Why? (How do you know?) |

*See discussion section for further clarification of this element.

| CONCRETE | NONSENSE |
|---|---|
| Missing conclusion | |
| All frogs jump. | All blims jump. |
| Shelley is a frog. | Shelley is a blim. |
| So? (What follows?) | So? (What follows?) |

Test-retest reliability of the instrument was established with a subgroup of the sample. There were five children each from ages five, seven and nine, for a total of fifteen subjects. One week intervened between testing sessions. A high reliability of .88 was established.

Procedure

A team of five testers was carefully trained to administer the test of logic. Included in the training program were sessions devoted to listening to tape recordings of children of various ages responding to the instrument followed by a critique of the procedures. All testers were required to administer the instrument to several children prior to actual data collection and to tape record these interactions. These tapes were reviewed and individual feedback sessions were held to insure that uniform testing procedures would be followed.

Data were collected through an individual oral session with each child in a quiet private room located in each school. Each child's responses were recorded on test forms and simultaneously tape recorded. The first few minutes of each session were used to establish rapport, obtain background information on the child, and introduce the test with the sample item. Following the child's response to the sample item, he was told the correct answer. On the test proper, testers were instructed not to indicate to the child whether or not his response was correct, but to merely respond with a noncommittal "OK" before proceeding to the next item.

To provide closure for the child at the end of the session, he was asked a few questions about himself and given the opportunity to listen to that segment of his tape. The child was requested not to share the content of the session with other children. Each session lasted approximately twelve minutes. Counterbalancing was utilized across all age levels to eliminate the effects of sample item, tester, room, and time of day.

Results

Each protocol was scored by two judges working independently. Out of a total of 1680 items to be scored (12 x 140 subjects) there was disagreement on only 14 items. In these few cases of disagreement, the tape recordings were consulted and a mutual decision between the two judges was reached.

A 7 x 2 x 3 factorial analysis of variance with repeated measures on the last two factors was employed for the study (Winer, 1971, pp. 539-559). The factors consisted of seven levels of age, two levels of content (nonsense and concrete), and three levels of element. The results of this analysis are presented in Table 1. As can be seen from this table, a significant value beyond the .01 level was obtained for the three main effects of age $F$ (6,133)=22.75, content $F$ (1,133)=8.31 and element $F$ (2,266)=152.77; as well as for two interactions, age x content $F$ (6,133)=5.75 and age x element $F$ (12,266)=5.74. In addition, the proportion of variance accounted for by the main effects of age and element was 18.63% and 24.81% respectively. The proportion of variance accounted for by all significant main effects and interactions was 50.06%

Insert Table 1 about here

The conservative Scheffé test (Kirk, 1968, p. 306) was deliberately utilized as the a posteriori measure since some of the assumptions of the analysis of variance had not been met. The results of the test for differences concerning the main effect of age are found in Table 2. As can be seen from this table, the mean differences between all age groups are significant except the difference between age nine and age ten.

Insert Table 2 about here

This pattern is confirmed by the data presented in Table 3 which show a definite progression in frequency and percentage of correct responses from age four to age nine with only a small increment from age nine to age ten. Thus, hypothesis one is confirmed.

Insert Table 3 about here

The Scheffé test was also utilized to determine where significant differences occurred between elements. The analysis revealed that there were significant differences at the .01 level between conclusions and major premises, and minor premises and major premises; but the difference between scores on the conclusion and minor premise was not found to be significant. Hence, hypothesis two was only partially confirmed.

The significant interaction effect for age x content reflected the fact that the magnitude of the difference between the nonsense and concrete

TABLE 1

ANALYSIS OF VARIANCE FOR AGE, CONTENT, AND ELEMENT

| Source | SS | df | MS | F | Proportion of Variance Accounted for |
|---|---|---|---|---|---|
| Between subjects | | | | | |
| Age | 137.21 | 6 | 22.87 | 22.75* | 18.63% |
| Subjects within groups | 133.66 | 133 | 1.01 | | |
| Total | 270.87 | 139 | | | |
| Within subjects | | | | | |
| Content | 1.46 | 1 | 1.46 | 8.31* | .20% |
| Age x Content | 6.05 | 6 | 1.01 | 5.75* | .82% |
| Content x Subjects within groups | 23.32 | 133 | .18 | | |
| Element | 182.72 | 2 | 91.36 | 152.77* | 24.81% |
| Age x Element | 41.22 | 12 | 3.43 | 5.74* | 5.60% |
| Element x Subjects within groups | 159.07 | 266 | .60 | | |
| Content x Element | 1.11 | 2 | .56 | 3.08 | |
| Age x Content x Element | 2.25 | 12 | .19 | 1.03 | |
| Content x Element x Subjects within groups | 48.30 | 266 | .18 | | |
| Total | 465.50 | 700 | | | 50.06% |

*Significant beyond the .01 level

TABLE 2

SCHEFFÉ TEST FOR DIFFERENCES BETWEEN MEANS BY AGE

(Total Correct Responses)

| | | Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 | 6 | 7 | 8 | 9 | 10 |
| Age | 4 | .95* | 2.80* | 4.50* | 5.55* | 6.40* | 6.50* |
| | 5 | - | 1.85* | 3.55* | 4.60* | 5.45* | 5.55* |
| | 6 | | - | 1.70* | 2.75* | 3.60* | 3.70* |
| | 7 | | | - | 1.05* | 1.90* | 2.00* |
| | 8 | | | | - | .85* | .95* |
| | 9 | | | | | - | .10 |

* Significant beyond the .01 level.

TABLE 3

Responses by Age and Element

(Frequency and percentage of correct responses)

| Age | Conclusion | | Minor Premise | | Major Premise | | Total | |
|---|---|---|---|---|---|---|---|---|
| | No. correct | % of possible | No. correct | % of possible | No. correct | % of possible | No. correct | % of possible |
| 10 | 78 | 97.5 | 76. | 95.0 | 23. | 28.8 | 177 | 73.8 |
| 9 | 77 | 96.3 | 76 | 95.0 | 22 | 27.5 | 175 | 72.9 |
| 8 | 71 | 88.8 | 69 | 86.3 | 18 | 22.5 | 158 | 65.8 |
| 7 | 65 | 81.3 | 61 | 76.3 | 11 | 13.8 | 137 | 57.1 |
| 6 | 51 | 63.8 | 44 | 55.0 | 8 | 10.0 | 103 | 42.9 |
| 5 | 21 | 26.3 | 28 | 35.0 | 17 | 21.3 | 66 | 27.5 |
| 4 | 15 | 18.8 | 28 | 35.0 | 4 | 5.0 | 47 | 19.6 |

content was not consistent across all age levels. In order to determine exactly at which ages the difference between nonsense and concrete content is significant, tests for the difference between simple main effects were computed (Winer, p. 544). These pair-wise comparisons presented in Table 4 revealed that there were significant differences in favor of the concrete content at ages four, five and six and in favor of the nonsense content at ages seven and ten. No significant differences were found at ages eight and nine.

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Insert Table 4 about here

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An inspection of the data revealed that the significant interaction effect for age x element could be accounted for primarily by the findings for ages four and five. While subjects were able to generate more correct conclusions than minor premises from ages six through ten, at ages four and five a greater frequency of minor premises over conclusions was obtained. (See Table 3). Further, as can be seen in Table 3 the number of correct major premises produced increased regularly with age, except at age five where an unusually high number of correct major premises was produced. Perusal of the test protocols indicated that a few children at age five, who were presented the sample item with a missing major premise, patterned all their responses on the sample item. Hence, these children responded with the major premise on all the syllogisms, thus inflating the number of correct major premises at this age level.

## Discussion

As hypothesized, there was a developmental sequence in the ability of children from ages four to ten to supply missing elements of syllogisms.

TABLE 4

DIFFERENCES BETWEEN NONSENSE & CONCRETE CONTENT

RESPONSES BY AGE LEVEL

| Age | Content | | t |
|---|---|---|---|
| | Nonsense | Concrete | |
| 10 | 91 | 86 | 3.27* |
| 9 | 88 | 87 | .64 |
| 8 | 78 | 80 | -1.29 |
| 7 | 71 | 66 | 3.23* |
| 6 | 46 | 57 | -7.10* |
| 5 | 20 | 46 | -16.78* |
| 4 | 20 | 27 | -4.50* |

*Significant beyond the .01 level.

There is a definite progression with age which continues up to age nine at which point there is a leveling-off effect. This developmental sequence in the supplying of missing propositions is assumed by the investigators to represent a steady increase in the children's deductive reasoning ability. There were a few children among the four- and five-year-olds, however, whose scores approximated the average score of children in the eight-, nine-, and ten-year-old groups. The only items these younger children did not generate were the missing major premises, thus they had approximately two-thirds of the items correct. This behavior is consistent with the investigators' previous observations that some children of four and five are capable of doing logical reasoning. Further, these findings lead to questioning Piaget's contention that children are not able to handle formal reasoning until approximately ages 11 or 12. Instead, they suggest that a too global definition of logic obscures mastery of specific principles by young children.

Concerning the second hypothesis which deals with the hierarchical difficulty of the syllogistic elements, it was found that children were able to generate missing conclusions much more easily than they were able to generate missing major premises. As noted in Table 3, there was a wide range of correct responses for generating missing conclusions, i.e., 19% to 98%. The range of correct responses for missing major premises was considerable more constricted, from 5% to 29%. Thus even by age ten though most of the children were able to supply virtually all of the missing conclusions, they were able to supply less than a third of the missing major premises. A tabulation of all responses revealed that on those syllogisms requiring a child to generate major premises a common

error was to repeat the minor premise. Thus, even on these syllogisms there was a tendency on the part of the children to respond with the particular rather than make the necessary leap to the formulation of a generalization.

An inspection of the data showed that the test items for generating minor premises were actually operating as syllogisms with missing conclusions. Therefore, Hypothesis 2 did not receive adequate testing for the difference between missing minor premises and the other two elements. A new format for assessing the generation of missing minor premises has been developed in consultation with an additional logician. This format is as follows:

Revised format for missing minor premise

All animals have fur.

Therefore, Marion has fur.

Why? (How do you know?)

A study is currently underway to further test Hypothesis 2 utilizing the revised format for missing minor premises.

In summary, the major conclusions of the study are as follows:

1. There is a developmental sequence in the ability of children from ages four to ten to supply missing elements of syllogisms. The younger the age, the lower is the score.
2. There is a hierarchy of difficulty for all subjects in supplying some missing portions of syllogisms with the missing conclusion being easier than the missing major premise.

These conclusions are applicable to subjects similar to those in this study. Further research is necessary at this point to determine the generalizability

of the results to children of varying backgrounds. Since it has been shown that for children as young as four an instrument requiring the generation of logical responses is a viable technique, further use of similar instrumentation in future studies appears warranted. Subsequent developmental studies might also increase the age range explored and systematically extend the logical principles investigated. While the value of this study is primarily heuristic in nature, the findings have practical implications as well. Teachers and curriculum developers may be assisted by the knowledge that some children as young as age four are able to generate logical conclusions. This knowledge should influence in particular the types of questions teachers use and their expectations in general.

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